CROSSWIND COEFFICIENTS OF DIFFUSION AND THEIR CORRELATION WITH MICROMETEOROLOGICAL PARAMETERS

SUZANNE E. DE CARRE

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Lieutenant, United States Naval Reserve

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the requirements for the degree of

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ABSTRACT

Diffusion measurements were made at the Round Hill Field Station Nebraska in the year 1957. These measurements were used to calculate σ_y, the LaGrangian standard deviation in the direction lateral to the mean wind for a series of experimental runs under varying conditions of thermal stability, and horizontal and vertical wind shear. A relationship between σ_y and the downwind distance was derived from Sutton's equation for an elevated point source. σ_y was calculated for the various runs of data and correlated with the crosswind and downwind distances. Correlations were worked out between (i) σ_y and the standard deviation of the wind angle σ_A, (ii) σ_y and the contour profile number p, and (iii) σ_y and the stability ratio. A marked correlation was found for σ_A the azimuth wind variation.

The writer wishes to express her appreciation for the assistance and encouragement given her by Professor Frank L. Martin of the U. S. Naval Postgraduate School in this investigation.

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LIST OF ILLUSTRATIONS

SYMBOLS

C_x, C_y, C_z	-	Generalized diffusion coefficients
c_o	-	Concentration of aerosol along main axis
c	-	Concentration not along main axis
h	-	Height of the source above the ground
Q	-	Source strength
r	-	Correlation coefficient
$R(\xi_y)$	-	Lagrangian autocorrelation coefficient of velocity component of lag
u	-	Wind in the x-direction
σ_A	-	Standard deviation of azimuth wind angle
σ_y	-	Lagrangian deviation along y-axis
σ_z	-	Lagrangian deviation along z-axis
u_2	-	Wind speed at 2 meters

1. Introduction

During the fall of 1957, a series of diffusion experiments from a steady state point source was conducted at the Round Hill Field Station in Nebraska. The sampling array consisted of three overlapping, independently operated networks at travel distances of 50, 100, and 200 meters. During the experiments, time-mean concentrations for sampling intervals of .5, 3, and 10 minutes were obtained for each travel distance. A schematic diagram of the field installation is shown by Figure 1. The ten-minute network comprised of individual stations located at a height of 1.5 meters and were spaced at 3-degree intervals along 180 degrees of arc: sampling stations for the three-minute network were at a height of 1.5 meters and spaced at 1.5 degree intervals along an arc of 150 degrees.

A sulfur dioxide generator was used to supply the tracer. A point source of strength 100 g per sec was required during conditions of thermal instability while an emission rate of half that amount was sufficient under nighttime thermal conditions of thermal stability. Prior to the start of the experiment, the tracer was permitted to traverse the entire network. The three sampling networks were then turned on simultaneously and each operated for the appropriate length of time. Aspiration of the impingers was provided by ten vacuum tanks. Error introduced into the concentration measurements by the operation of the vacuum system was estimated to be less than five percent.

Meteorological instrumentation included: a cup anemometer and sensitive azimuth vane located at a height of two meters near the source;

A - anemometer
C - control box
D - oximuth vane

S - SO_2 release point
PT - portable tower
T - truck

X - bivane

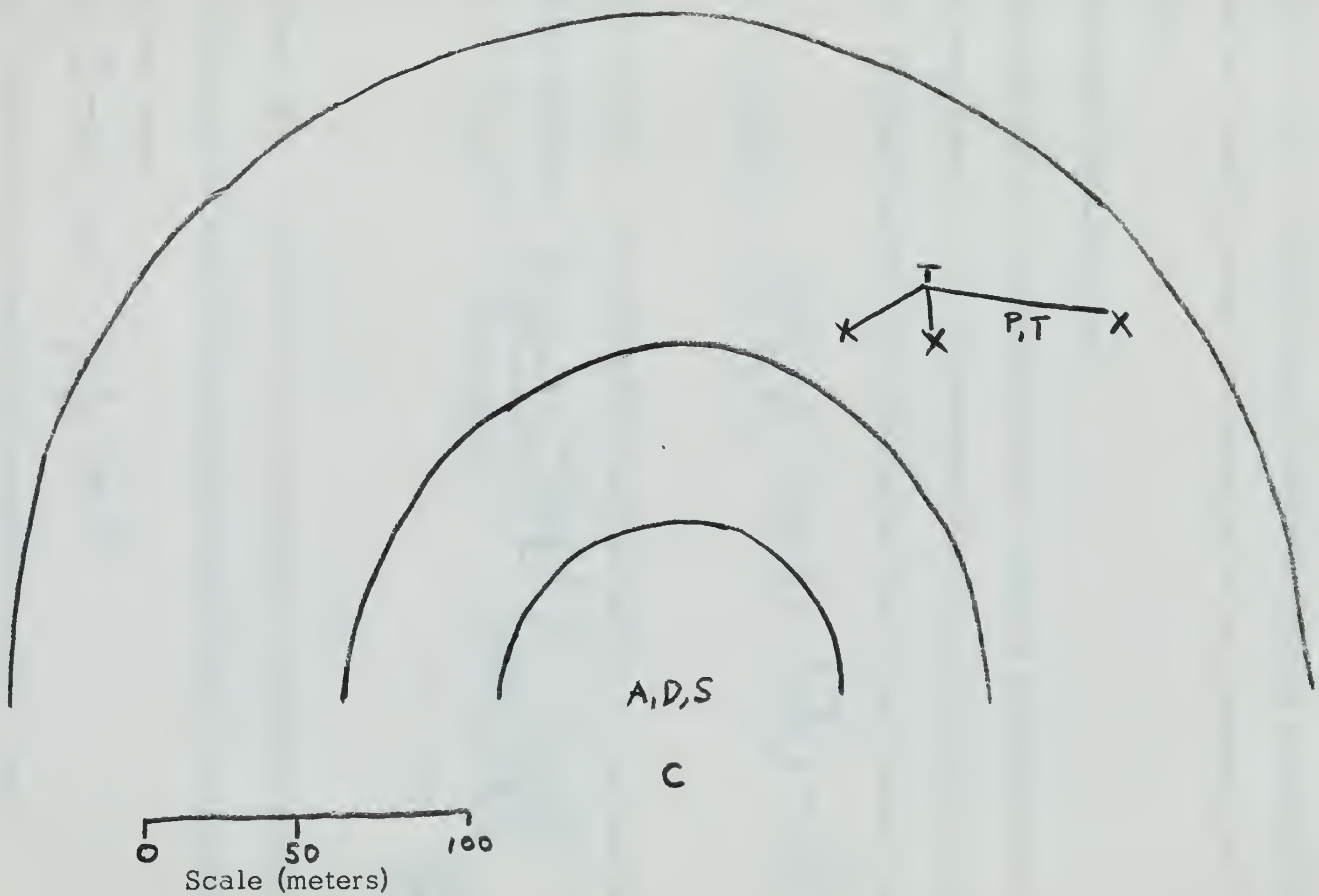


Fig. 1. Schematic diagram of field installation used for 1957 experiments at Round Hill

cup anemometers and ventilated thermocouples at heights of 1.5, 3, 6, and 12 meters on a portable tower; and for most experiments, five bivanes equipped with heated thermocouple anemometers. The operation of all meteorological instrumentation was controlled by a timer located within the recording truck. A twenty-minute observation period centered on the ten-minute gas sampling period was employed for the meteorological instruments.

2. Theoretical considerations:

Assuming that the mean concentrations within a diffusion cloud are distributed laterally by a two-dimensional normal distribution, Sutton has shown that the steady-state concentration from a point source is given by:

$$(1) \quad \bar{C}(x,y,z) = \frac{2Q}{\pi u \sigma_y \sigma_z} \exp\left[-\left(\frac{y^2}{2\sigma_y^2} + \frac{z^2}{2\sigma_z^2}\right)\right]$$

for a ground source. For an elevated source of height, h, the corresponding equation becomes:

$$(2) \quad \bar{C}(x,y,z) = \frac{Q \exp(-y^2/2\sigma_y^2)}{\pi u \sigma_y \sigma_z} \left\{ \exp\left[\frac{-(z-h)^2}{2\sigma_z^2}\right] + \exp\left[\frac{-(z+h)^2}{2\sigma_z^2}\right] \right\}$$

Sutton's reasoning, in addition to the assumption of the Gaussian distribution of pollutant, is that the concentration shall satisfy the following boundary conditions:

(1). $\bar{C} \to 0$, as $x, y, z \to 0$

(2). The downward transport at the earth's surface is zero.

(3). The rate of the total transport of contaminant through any downwind plane is constant and equal to the generation rate at the source.

In this study expression for σ_y and σ_z of the form

$$\sigma_y = Bx^b, \quad b > 0$$

will be sought.

Sutton [3] made certain assumptions regarding the form of the Lagrangian autocorrelation function R (ξ) which relates the y-component of velocity with that existing for the same particle at time ξ later. He then obtained:

(4) $$\sigma_y^2 = \frac{1}{2} C_y^2 x^{2-n}$$

(5) $$\sigma_z^2 = \frac{1}{2} C_z^2 x^{2-n}$$

Here C_y, C_z are called the generalized diffusion coefficients. Sutton [3] has obtained formulas C_y, C_z in terms of the gustiness of the wind. The particular formulas for C_y, C_z may be found on page 251 of [3].

The expressions for σ_y^2, σ_z^2 of (4), (5) are usually introduced into (1) or (2) at this point. Barad and Haugen [1] have tested Sutton's theory using the equation modified in this way. However, the values they found did not agree with n = 2p/p+ 1. Thus in this paper, the more general Sutton theory of Equations (1) and (2) has been used, with the object of determining empirical information regarding σ_y and σ_z.

Let c_o be the axial concentration at a given downwind distance x, and c_1 the concentration at (x,y,z) where, in the major part of the Round Hill data, z= 1.5 meters. In order to obtain σ_y, σ_z as a function of x, the assumption was made that these parameters did not vary over the measuring range lateral to the axis. Therefore, using c_o with y = 0 in Equation (2) we obtain:

$$(6) \quad \frac{c_1}{c_0} = \exp\left(-y^2/2\sigma_y^2\right) .$$

On taking logs of both sides of Equation (6)

$$(7) \quad \sigma_y^2 = \frac{y^2}{2\ln(c_0/c_1)}$$

This was the main working equation of this paper. A similar procedure will be outlined for σ_z, although no detailed computations for σ_z have been obtained.

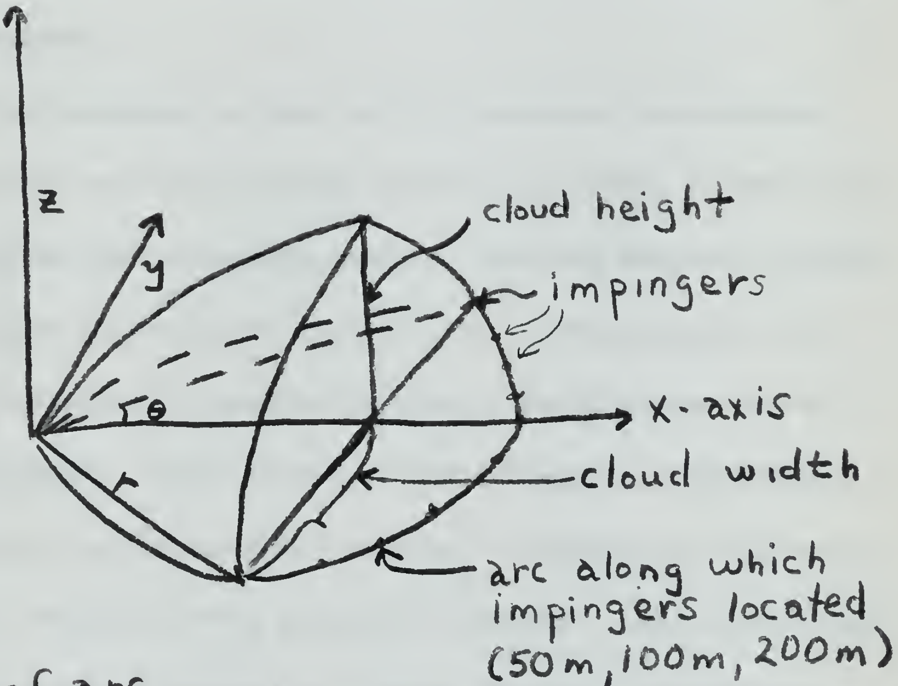
3. Research objectives and results:

The first problem of this study was to determine a relationship between σ_y and the downwind distance x along the mean wind. An equation of the form

$$\sigma_y = Bx^b, \; b > 0$$

was tested. Secondly, it was desired to determine the empirical relationship between σ_y and x and y, where y is the distance lateral to the wind axis.

A chemical cloud may be pictured ideally as shown in Figure 2. The data [2] presented concentrations at only three downwind distances along the axis: at 50 meters, 100 meters and 200 meters. The concentration,



r = radius of arc

$y = r \sin\theta$

$x = r \cos\theta$

Figure 2. Sulfur dioxide cloud from point source

c_o, at other points along the x-axis is also needed. For each of the 10 runs, the known concentrations were plotted on log-log paper and c_o for each value of x in the range 50 to 200 meters was determined.

Under extremely stable conditions the cloud, as might have been predicted, showed limited spreading and very little could be deduced as to the relationship of σ_y to x and y. In unstable conditions, the cloud spread rapidly vertically and laterally. Results of the calculations are shown in the Appendix.

In Sutton's hypothesis, a cloud with its maximum concentration along the mean wind axis was assumed to be symmetrical. It was found, in practice, that the cloud was asymmetrical, and that maximum concentration did not quite coincide with the direction of the maximum wind frequency. The x-axis was therefore assumed to be along the line of maximum concentration. There were also other directions along which the concentrations reached secondary maxima, with rather closely associated secondary maxima of wind frequency direction. These distributions represented superimposed bimodal or trimodal Gaussian distributions. The variance σ_y of the Sutton theory was assumed, however, to be that of a unimodal Gaussian distribution, Eq. (2), but actually varied markedly from one side of the major axis of the cloud to the other, and increased also with the length of the averaging time.

There was, in most instances, a rapid decrease of σ_y near the axis. For a possible explanation, let us examine the equation:

$$\sigma_y^2 = \frac{y^2}{2 \ln C_o/C_1}$$

For points near the axis, that is, for c_1 very nearly equal to c_o, the ratio c_o/c_1 approaches one. The natural log of one is zero, and values of the log function near one are very small. The concentration c_1 near the axis does not decrease rapidly at first as y increases; however y increases to the second power and the value of σ_y increases very rapidly. At a short distance from the axis the concentration c_1 begins to decrease appreciably and the value of σ_y then begins to decrease with an increase in y. This peaking of σ_y also happens to some extent as secondary maxima concentration-directions are sampled.

Noting that there was a straight-line decrease in σ_y with a decrease of x, when these coordinates were plotted on log-log paper, for impingers well-removed from concentration maxima, an empirical relationship between σ_y and $x^b y^m$ was sought. The following relationship was tested:

$$\sigma_y = D x^b y^m \tag{7}$$

where D, m and b are unknowns. The results from use of Eq. (7) indicated that both m and b were negative. However, observationally b should be positive when x is varied, while keeping y constant. Hence the assumed dependence upon y was rejected.

The equation was modified to the following form:

$$\sigma_y = B x^b \tag{8}$$

In order to get a good fit for b in each run, the statistical method of least squares was used.

Eq. (8) was reduced to the following form:

$$\log \sigma_y = \log B + b \log x \quad (9)$$

Summing up this equation into the least squares form:

$$\Sigma \log \sigma_y = N \log B + b \Sigma \log x$$

$$\Sigma \log \sigma_y \log x = \log B \Sigma \log x + b \Sigma (\log x)^2 \quad (10)$$

where N is the number of points for which corresponding σ_y and x are available on the measuring arc. From these equations, b and B were obtained from each ten-minute run except #1 where the thermal stability prevented the cloud from spreading to any extent. These values are presented together with those of σ_A, SR and p (the last two of these parameters will be defined on page 10 in Table 1.

Run	B	b	σ_A	SR	p
2	.0276	1.550	16.5	.0243	.204
3	2.9800	0.340	12.9	.0035	.0867
4	1.5600	0.873	16.7	.0118	.128
5	4.4500	0.180	9.2	.0057	.058
6	4.3600	0.656	10.4	.0407	.197
7	.4170	0.832	13.5	.0159	.137
8	4.32×10^{-6}	2.50	12.8	.0072	.153
9	8.17×10^{-7}	3.01	13.1	.0048	.070
10	.0010	2.35	20.7	.0048	.099

Table 1. Values of B and b and micrometeorological parameters.

The values of σ_A which appear in Table 1 were obtained from [2]. The stability ratio, SR, was defined from the equation:

(11) $$SR = \frac{(T_{12} - T_{1.5}) + (Z_{12} - Z_{1.5})\gamma_d}{u_z^2}$$

which is essentially a measure of the Richardson number. The profile contour number p, which was also used extensively in the Sutton theory, is defined by the equation:

(12) $$u = u_1 (z/z_1)^p$$

Values of winds at 12 and 6 meters from reference [2] were used in computing p.

4. The correlation analysis.

The parameters B and b which specify σ_y were linearly correlated with each of σ_A, SR and p. The number of independent cases in each sample was N=9. The results of the correlation were as follows:

1 $r(B, \sigma_A) = -.457$

2 $r(b, \sigma_A) = -.844$

3 $r(B, SR) = -.207$

4 $r(b, SR) = -.0946$

5 $r(B, p) = -.421$

6 $r(b, p) = -.601$

The minimum correlation coefficient which is significant at the .05 level, based on nine independent cases is .816; at the .10 level, the minimum is .796.

Correlation (2) is significant at the .05 level.

Correlations (1), (5) and (6) may be significant but not at the levels of .05 or .1. The others were not significant at all.

It can be concluded that it may be possible to specify $\sigma_y = Bx^b$ on the basis of the micrometeorological parameters σ_A and p although a larger sample of diffusion data would be necessary to establish adequate significance levels.

5. Suggestions for future research.

One of the assumptions made was that σ_y did not vary appreciably over a lateral cross-section (at fixed x) through the cloud. The value obtained using this assumption was therefore a first approximation. It was found that the values thus obtained did vary laterally especially on passing through a secondary maximum of concentration. It would be desirable to determine values of σ_y which are relatively constant with y in spite of secondary maxima of wind frequencies.

The data for this experiment can also be analyzed for σ_z. Making the assumption, again, that σ_y and σ_z do not vary appreciably in the measuring range lateral to the axis, the following equation was derived in the same manner as the equation for σ_y, using the levels of 1.5 and 2.5 meters for which data are available:

$$(12) \quad \frac{c_{2.5}}{c_{1.5}} = \left\{ \frac{\exp\left(-\frac{(1.0)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(4.0)^2}{2\sigma_z^2}\right)}{1 + \exp\left[-\frac{(3.0)^2}{2\sigma_z^2}\right]} \right\}$$

If

$$A = \exp \frac{-1.0}{2\sigma_z^2}$$

the resultant equation is:

$$(13) \quad \frac{C_{2.5}}{C_{1.5}} = \frac{A + A^{16}}{1 + A^{9}}$$

From this equation, A may be found, and from that $\sqrt{z}$.

In order to establish firmer tests of correlation significance, a greater number of runs should be analyzed using Eq. (8).

It is also desirable to test the diffusion model of Cramer et al [2] in order to see if their diffusion parameters are more nearly predictable from the meteorological variables than of this study.

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APPENDIX

Right side-10 minutes

Run 1 - 100 meters

x	y	c_1 (mg/m^3)	c_o (mg/m^3)	σ_y
99.86	5.23	190.00	285	6.79
99.45	10.45	53.90	285	5.73
98.77	15.64	6.15	286	5.41
97.82	20.29	0.752	288	7.50
96.59	25.88	0.106	290	9.17

Run 1 - 200 meters

199.7	10.5	54.9	117.5	8.53
198.9	20.9	5.96	118.	8.55
197.5	31.3	0.231	119.	8.85

Run 2 - 100 meters

99.86	5.23	22.5	23.0	32.3
99.45	10.45	22.1	23.3	33.5
98.77	15.64	20.5	23.6	28.3
97.82	20.29	18.6	23.8	28.8
96.59	25.88	19.9	24.0	43.0
95.11	30.90	12.1	24.2	26.3
93.36	35.84	9.50	24.6	26.0
91.36	40.67	7.53	24.0	26.4
89.10	45.40	4.53	25.5	24.4
86.60	50.00	1.89	26.0	21.8

Right side-10 minutes

Run 2 - 100 meters (continued)

x	y	c_1	c_o	σ_y
83.87	54.46	1.87	26.8	23.8
80.90	58.78	1.73	27.5	25.0
77.72	62.93	2.49	28.5	28.5
74.31	66.91	2.10	29.7	29.1
70.71	70.71	0.465	31.0	24.4
66.91	74.31	0.134	32.0	22.4
62.93	77.72	0.46	34.0	21.4

Run 2 - 200 meters

x	y	c_1	c_o	σ_y
199.7	10.5	5.50	5.75	18.7
198.9	20.9	5.74	5.82	33.0
197.5	31.3	5.68	5.83	40.3
195.6	41.6	4.69	5.90	61.1
193.2	51.8	3.59	6.00	52.1
190.2	61.6	1.92	6.10	40.6
186.7	71.7	2.28	6.30	50.3
182.7	81.3	1.66	6.42	49.3
178.2	90.8	1.07	6.60	47.6
173.2	100.0	1.26	6.80	54.4
167.7	108.9	0.841	7.20	52.4
161.8	117.6	0.491	7.60	50.2
155.4	125.9	0.301	7.82	49.3

Right side - 10 minutes

Run 2 - 200 meters (continued)

x	y	c_1	c_o	σ_y
148.6	133.8	0.079	8.60	43.8
		Run 3 - 100 meters		
99.86	5.23	59.1	73.9	9.21
99.45	10.45	44.8	74.5	10.3
98.77	15.64	25.4	75.0	10.2
97.82	20.29	13.3	75.5	10.8
96.59	25.88	3.84	76.0	10.5
95.11	30.90	0.509	77.0	13.2
93.36	35.84	0.179	78.0	10.2
91.37	45.40	0.061	79.0	10.7
89.10	35.84	0.203	78.0	10.3
		Run 3 - 200 meters		
199.7	10.5	20.1	22.5	22.0
198.9	20.9	10.3	22.7	16.9
197.5	31.3	3.24	23.0	15.7
195.6	41.6	0.855	23.5	16.5
193.2	51.8	0.102	24.0	15.7
		Run 4 - 100 meters		
99.96	5.23	52.2	55.0	19.8
99.45	10.45	42.5	55.3	14.6
98.77	15.64	30.3	55.7	13.6

Right side - 10 minutes

Run 4 - 100 meters (continued)

x	y	c_1	c_o	σ_y
97.82	20.29	24.5	56.0	15.8
96.59	25.88	20.2	56.5	18.2
95.11	30.90	22.3	57.0	22.8
93.36	35.84	22.8	57.5	26.5
91.36	40.67	21.5	58.0	29.7
89.10	45.40	17.6	59.0	29.3
86.60	50.00	14.2	60.0	29.5
83.87	54.46	16.5	61.0	33.8
80.90	58.78	6.86	62.0	28.3
77.72	62.93	4.25	63.0	27.2
74.31	66.91	3.63	65.0	28.3
70.71	70.71	2.30	66.0	27.4
66.91	74.31	1.16	69.0	26.1
62.93	77.72	1.37	71.0	27.5
58.78	80.90	0.344	73.0	24.8
54.46	83.87	0.053	77.0	26.6

Run 4 - 200 meters

199.7	10.5	12.8	14.2	23.0
198.9	20.9	11.3	14.3	30.2
197.5	31.3	10.4	14.4	38.5
195.6	41.6	8.2	14.5	38.7

Right side - 10 minutes

Run 4 - 200 meters (continued)

x	y	c_1	c_o	σ_y
193.2	51.8	4.96	14.8	35.0
190.2	61.6	5.58	15.0	43.9
186.7	71.7	4.96	15.4	47.6
182.7	81.3	4.41	15.8	50.7
178.2	90.8	3.84	16.2	53.9
173.2	100.0	3.05	16.5	54.4
167.7	108.9	2.69	17.3	55.3
161.8	117.6	1.93	19.0	57.0
155.4	125.9	0.950	20.3	50.7
148.6	133.8	0.610	22.0	49.7
141.4	141.4	0.410	24.0	48.8
133.8	148.6	0.197	27.0	47.2

Run 5 - 100 meters

x	y	c_1	c_o	σ_y
99.86	5.23	256	284	13.5
99.45	10.45	209	286	12.2
98.77	15.64	70.8	288	8.92
97.82	20.29	19.8	290	8.75
96.59	25.88	2.47	295	8.35
95.11	30.90	0.671	300	8.83
93.36	35.84	0.239	310	9.43
91.38	40.67	0.160	320	10.4

Right side - 10 minutes

Run 5 - 100 meters (continued)

x	y	c_1	c_o	σ_y
89.10	45.40	0.166	330	11.6

Run 5 - 200 meters

x	y	c_1	c_o	σ_y
199.7	10.5	75.5	137.	9.60
198.9	20.9	30.8	137.	12.1
197.5	31.3	2.24	137.	10.9
195.6	41.6	0.344	137.	12.0

Run 6 - 100 meters

x	y	c_1	c_o	σ_y
99.86	5.23	79.7	89.9	12.5
99.45	10.45	64.3	89.9	12.6
98.77	15.64	55.3	90.0	14.2
97.82	20.29	50.7	91.0	18.7
96.59	25.88	38.5	91.5	19.6
95.11	30.90	20.1	92.0	17.2
93.36	35.84	8.79	93.0	16.4
91.36	40.67	1.64	93.5	14.2
89.10	45.40	0.102	94.5	12.2

Run 6 - 200 meters

x	y	c_1	c_o	σ_y
199.7	10.5	20.5	28.4	12.5
198.9	20.9	16.1	28.4	19.7
197.5	31.3	14.5	28.4	27.9
195.6	41.6	11.8	28.8	31.1

Right side - 10 minutes

Run 6 - 200 meters (continued)

x	y	c_1	c_o	σ_y
190.2	61.6	8.43	29.3	32.7
186.7	71.7	0.662	30.0	25.8
182.7	81.3	0.200	31.0	25.5
		Run 7 - 100 meters		
99.86	5.23	35.8	39.9	13.8
99.45	10.45	35.3	39.9	21.3
98.77	15.64	34.8	39.9	29.4
97.82	20.29	26.1	40.0	22.0
96.59	25.88	15.4	41.0	18.5
95.11	30.90	8.05	41.2	16.8
93.36	35.84	4.66	41.5	17.1
91.36	40.67	2.21	41.8	16.8
89.10	45.40	0.500	42.3	15.2
86.60	50.00	0.065	43.0	13.8
		Run 7 - 200 meters		
199.7	10.5	12.0	13.7	20.6
198.9	20.9	8.38	13.8	20.9
197.5	31.6	5.41	14.0	22.5
195.6	41.6	3.00	14.2	23.6
193.2	51.8	1.33	14.5	23.7
190.2	61.6	0.615	15.0	24.4
186.7	71.7	0.239	15.7	24.8

Right side - 10 minutes

Run 8 - 100 meters

x	y	c_1	c_o	σ_y
99.86	5.23	47.7	49.7	21.9
99.45	10.45	34.4	49.7	13.1
98.77	15.64	20.5	29.7	11.3
97.82	20.24	8.14	49.7	10.6
96.59	25.88	1.55	50.3	9.8
95.11	30.90	0.410	51.5	9.9
93.36	35.84	0.109	51.8	10.2

Run 8 - 200 meters

x	y	c_1	c_o	σ_y
199.7	10.5	11.9	14.1	18.8
198.9	20.9	7.38	14.1	18.4
197.5	31.3	2.72	14.2	20.6
195.6	41.6	0.936	14.3	17.9
193.2	51.8	0.207	14.7	17.7

Run 9 - 100 meters

x	y	c_1	c_o	σ_y
99.86	5.23	51.1	59.2	11.2
99.45	10.45	47.7	59.2	15.9
98.77	15.64	40.4	59.2	17.1
97.82	20.29	38.2	59.2	21.6
96.82	25.88	23.9	59.8	19.2
95.11	30.90	12.4	60.0	17.4
93.36	35.84	6.73	62.0	20.2

Right side - 10 minutes

Run 9 - 100 meters (continued)

x	y	c_1	c_o	σ_y
91.36	40.67	2.92	64.0	16.4
89.10	45.40	0.686	65.0	15.0
86.60	50.00	0.127	75.0	14.0

Run 9 - 200 meters

x	y	c_1	c_o	σ_y
199.7	10.5	16.6	17.4	33.4
198.9	20.9	14.3	17.4	33.0
197.5	31.3	11.2	17.7	34.3
195.6	41.6	5.79	18.0	27.6
193.2	51.8	4.67	18.5	31.3
190.2	61.6	3.27	18.9	33.0
186.7	71.7	0.480	19.7	26.3

Run 10 - 100 meters

x	y	c_1	c_o	σ_y
99.86	5.23	24.8	28.4	11.6
99.45	10.45	20.2	28.4	12.6
98.77	15.64	16.1	29.0	14.4
97.82	20.29	16.0	29.5	18.4
96.59	25.88	13.8	30.2	21.4
95.11	30.90	14.4	32.0	24.8
93.36	35.84	20.2	33.5	28.3
91.36	40.67	24.2	37.2	43.9
89.10	45.40	19.0	39.0	37.8
86.60	50.00	16.6	39.7	37.9

Right side - 10 minutes

Run 10 - 100 meters (continued)

x	y	c_1	c_o	σ_y
83.87	54.46	14.2	45.3	35.8
80.90	58.78	10.3	47.5	33.6
77.72	62.93	4.87	49.2	29.3
74.31	66.91	2.19	50.1	26.7
70.71	70.71	1.94	58.0	27.1
66.91	74.31	2.86	67.0	29.6
62.93	77.72	4.72	78.0	26.6
58.78	80.90	3.50	87.0	32.3

Run 10 - 200 meters

199.7	10.5	3.03	4.71	11.2
198.9	20.9	3.79	4.71	31.8
197.5	31.3	4.26	4.9	59.1
195.6	4.6	3.23	5.0	44.2
193.2	51.8	2.92	5.1	48.9
190.2	61.6	1.46	5.2	45.0
186.7	71.7	1.00	5.3	39.2
182.7	81.3	1.43	5.4	49.6
178.2	90.8	2.79	5.6	76.5
173.2	100.0	3.49	6.1	94.4
167.7	108.9	2.41	6.8	75.5
161.8	117.6	3.11	7.2	90.2

Right side - 10 minutes

Run 10 - 200 meters (continued)

x	y	c_1	c_0	σ_y
155.4	125.9	2.78	8.3	85.0
148.6	133.8	1.05	9.5	63.8
141.4	141.4	0.597	10.0	58.6
133.8	148.6	0.527	11.0	60.3
125.9	155.4	0.967	13.0	68.6
117.6	161.8	1.17	17.0	69.7
108.9	167.7	0.166	19.0	54.7